HMMWV Power Inverter Candidate Selection Test Report

15 June 2001

Prepared for:

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1.0 SCOPE

1.1 Identification. The U.S. Marine Corps currently supports several surface vehicles, including the High Mobility Multi-purpose Wheeled Vehicles (HMMWV). U.S. Marine Corps Systems Command (MARCORSYSCOM) has realized the need to operate additional commercial off the shelf (COTS) computer devices in certain configurations of the HMMWV. This requirement includes an additional need for Alternating Current (AC) power in the HMMWV. MARCORSYSCOM submitted a request via the Commerce Business Daily (CBD) for a Direct Current (DC) to AC Power Inverter. This test report will describe the findings of the testing on the Inverter, the QP-1800 (submitted and sold by Iris Technology Corporation). Specifically, this report will address the specifications outlined in the CBD and the pertinent safety issues.

Space and Naval Warfare Systems Center (SPAWARSYSCEN) Charleston, Code 613 was selected as the agent to perform this testing with MARCORSYSCOM. The dates of the test were from May 21 to June 6, 2001. This test report will give the test results, and also provide recommendations, limitations, and constraints for these and future power inverters.

1.2 System Overview. The power inverter will support the current and future USMC Command, Control, Communications, Computer, and Intelligence (C4I) and IT components in the HMMWV vehicles. It must be able to use the provided power of 24 VDC, and must be able to provide 120 VAC 60 Hz Power. This power inverter is semi ruggedized, and meets other operational requirements, such as size and weight. The environmental requirements are listed in Table 1. The electrical requirements are listed in Table 2. Most of these were derived from the CBD.

Parameter	Value
Low Storage Temperature	-30°C
Low Operating Temperature	0°C
High Operating Temperature	60°C
High Storage Temperature	70°C
Standard Operating Relative Humidity	Not Specified
Maximum Operating Relative Humidity	Not Specified
Maximum Operating Altitude	Not Specified
Vibration, (Random) Non-operating	Per MIL-STD-810

Table 1 Environmental Requirements

Parameter	Value	Requirement
Continuous power	1500W	min
Surge power	3000W	min
Peak efficiency	85%	min
No load current draw	1A	max
Output frequency	60Hz	0.05%
Output waveform	5% THD	max
Input voltage Range	20-32 VDC	required
Output voltage	120 VAC	-10% +4%

Table 2 Electrical Requirements

1.3 Power Inverter Test Candidate. SSC Charleston was tasked to test 1 candidate system. That system is the QuietPower 1800, sold by Iris Technology. This is an 1800W Power Inverter, and meets most of the specs called out in the CBD. Figure 1 shows a picture of the Inverter. It is able to accept DC power from a HMMWV using the NATO slave receptacle, and it provides AC power to any normal AC device. The unit was received with a 12-foot 2/0 AWG Power Cable, with a NATO slave connection.

This is the cable used for the HMMWV tests. The unit is semi ruggedized, although it was not shock tested. It provides 120 VAC RMS Power at 2 GFCI protected receptacles on the inverter unit.

Figure 1: QP-1800

1.4 Document overview. This test report shall contain a factual representation of the results of the Power Inverter testing. The QP-1800 underwent several levels of testing. These tests were required to ensure that the unit not only satisfies the electrical requirements, but also to make sure the unit will be safe in an operational environment. The purpose of this test report is to document test results, and to assist MARCORSYSCOM in their decision-making process for the fielding and usage of the QP-1800 Power Inverter.

The report has been designed such that the main body of the document provides an overview of the test conduct. Specific test results are provided in Appendix A to allow examination of the data.

This test report is the property of MARCORSYSCOM, who shall direct any distribution of the test results. All pictures within the document were taken from the website, or taken during testing, or as documentation of the test and are not to be distributed without the consent of the vendor. Internal hardware component design is generally considered company proprietary.

1.5 Power Inverter Test Progression. The Inverter package was received at SPAWAR Systems Center Charleston from Quantico and inventoried. It was briefly examined to determine if it had all the features, components, and interfaces as described in Section 1.3 above. There were no exceptions, except that 4 black rubber shock mounts were also included. The system was placed in the Integration Lab, 06.A in Building 3112. The system was powered on and a basic hardware check was performed using the manufacturer's delivered Owner's Manual.

Functional performance testing was accomplished first, using a bench test configuration. Next, the electrical tests continued using power from a HMMWV. The operational and GFCI test occurred next, still using the power from the HMMWV.

Upon completion of the functional testing, the system was transported to the Environmental Lab, 4.7, Building 3113. Environmental test engineers controlled the environmental chambers (temperature, humidity, and altitude) and the vibration table, while the test analysts verified the operation of the system after each phase of the testing. Upon completion of environmental testing, the Inverter candidate was transported back to the Integration Lab, 06.A in Building 3112. Further explanations of the functional and environmental tests are provided in Section 3.

2.0 REFERENCED DOCUMENTS

2.1 Government.

a. MIL-STD-810E and F, Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, dated 14 July 1989 and 1 Jan 2000, respectively.
b. MIL-STD-810F(1), 1 Nov 2000

c. System Safety Plan for the Unit Operations Center (UOC) Combat Operations Center (COC), Draft Oct 2000
d. Performance Specification Logistics Management Information (LMI) MIL-PRF-49506 11 November 1996
e. MIL-HDBK-454A GENERAL GUIDELINES FOR ELECTRONIC EQUIPMENT, 3 Nov 2000
f. MIL-STD-882D System Safety, 10 Feb 2000
g. MIL-PRF-28800 TEST EQUIPMENT FOR USE WITH ELECTRICAL AND ELECTRONIC EQUIPMENT, GENERAL SPECIFICATION FOR, 24 Jun 1996
h. MIL-STD-1275B Characteristics of 28 Volt DC Electrical Systems in Military Vehicles, 20 Nov 1997
i. SPAWAR HMMWV Power Inverter Test Plan, dated 21 May 2001

2.2 Non-Government.

a. None

3.0 TEST RESULTS

3.1 Overview. The Inverter candidate was tested in accordance with the SPAWAR HMMWV Power Inverter Test Plan dated 21 May 2001. Test conduct generally did not deviate from the intended test plan with the exception of the addition of temperature testing. Originally, the test was designed to have only vibration testing done at the environmental lab. After negotiations with the environmental lab engineers, the team decided to perform temperature testing as well. This temperature testing would be abbreviated, but would test the specifications called out. The only other deviation from the test plan was that we used high amperage equipment for the GFCI tests.

The Inverter evaluation was targeted at the areas in which MARCORSYSCOM stressed importance and not focused on all of the individual areas that the QP-1800 Owner's Manual discussed. It was agreed that the most important issues were safety, and the operation of the GFCI outlets. These 2 issues are related, and a general discussion of GFCI will follow.

3.2 Functional Performance Test Results. The following sections shall describe the functional tests that took place. Some of the requirements (such as under/over voltage cutoff) had to be tested on the bench, with a variable power supply. However, some tests (such as surge power test) had to be conducted using the HMMWV battery because of limitations of the test equipment (the power supply only went up to 60 ADC). For more details on the test configurations, please reference the SPAWAR HMMWV Power Inverter Test Plan, dated 21 May 2001.

3.2.1 Bench Test Results. The bench testing used a power supply configuration similar to Figure 2. The test team also used voltmeters on the front end and back end. The test progression was that we hooked the Inverter to the test equipment, then started taking simple measurements.

3.2.1.1 No Load Current Draw. The no load current draw was taken with 24 VDC going into the Inverter. The no load reading was 1.01 Amp, which is very close to the specified value. (It is possible that this value could have varied depending on the voltage supplied, and cable gauge, although we did not test that. It was agreed that the value was acceptable.) The no load condition was also tested using the HMMWV.

3.2.1.2 Total Harmonic Distortion. Next the test team measured the output waveform distortion. The output signal was always 60Hz, and the total harmonic distortion (THD) was measured to be 0.54%

at 0W, and 0.52% at 500W on the bench. (Higher power measurements were taken using the HMMWV power.)

3.2.1.3 Output Frequency. The output frequency was monitored during all the tests using a Fluke Multimeter. The frequency never varied from 60.00 Hz.

3.2.1.4 Input Voltage Range. The normal operating voltage is 24 VDC. However, due to a variety of factors, the input voltage can vary greatly in an operational environment. The test team used the configuration in Figure 2, and varied the voltage being supplied by the DC power supply. The low and high voltage warning and shutdown were generally consistent with what was in the QP-1800 Owner's Manual. We tested the warning and shutdown voltages over a range of loads, and found the low voltage warning alarm came on at 21.2 VDC, and the under voltage shutdown was at 20.0 VDC. The high voltage alarm came on at about 31.7 VDC, and the shutdown occurred at 32.0 VDC. It should be noted that the voltage reading on the Inverter display is generally accurate, but is not as accurate as a voltmeter. The detailed results are in Appendix A.

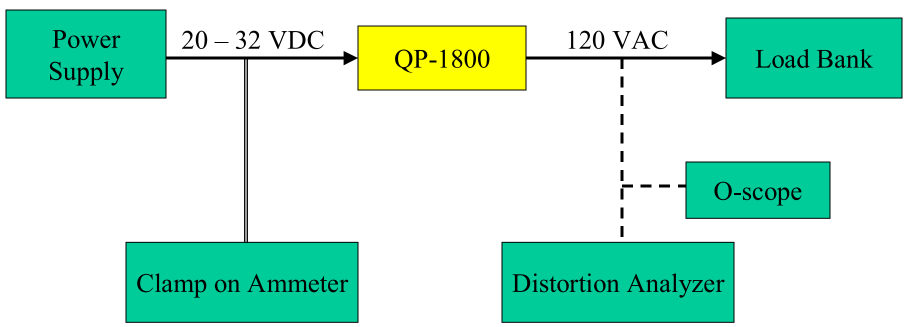

Figure 2: Bench Test Configuration in Lab

3.2.1.5 Output Voltage Range. The output voltage range of the inverter is required to be 120 VAC. We monitored the output voltage during all steps of the test; we found the output voltage to be relatively consistent, and well within the error range of –10% +4%. See the test results in the Appendix for more information.

3.2.1.6 Short Circuit Test. The primary purpose of the short circuit test was to make sure the unit would cut off power if the load was in a short circuit condition. This was performed using a Load transfer switch (Square D Double Throw 200A Load Transfer Switch). See Figure 3. The Inverter performed well, and the circuit breaker tripped. This satisfies the requirement of MIL-HDBK-454A, Guideline 8, for Electrical Overload Protection.

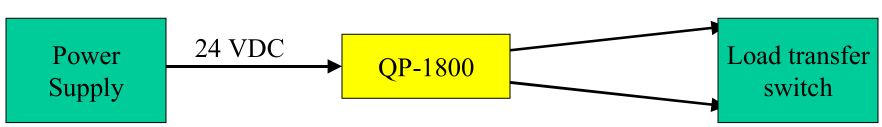

Figure 3: Short circuit test configuration

3.2.2 HMMWV Test Results. The HMMWV testing occurred using a configuration similar to Figure 4. Again, voltmeters were used on the front end and back end of the inverter to monitor input/output voltage and current. Because we were using the HMMWV for power, the input voltage to the inverter varied, but could not be controlled manually.

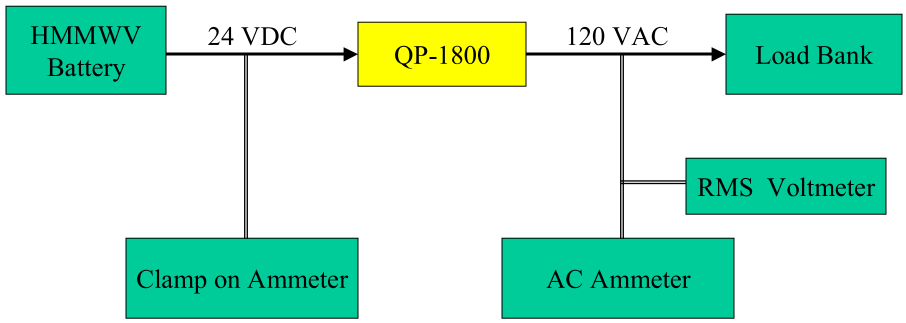

Figure 4: Bench Test Configuration in HMMWV

3.2.2.1 Continuous Power. The QuietPower 1800 is rated for 1800 Watts continuous load. The testing that was performed verified this operation. By increasing the load on the load bank, we took measurements to calculate what the effective Power was across the load. The inverter had no problem supporting 1800 W, even with varying input voltage. Details of this test can be found in Appendix A.

3.2.2.2 Surge Power. The QP-1800 is rated for 2900 W surge power. The owner's manual states that the unit can support 2900 W for up to 5 seconds. We tested this. Increasing the load on the load bank, we also took current and RMS voltage measurements to verify the Power across the load. The inverter was able to support this load for 5 seconds. It should be noted that there was a noticeable difference in the operation of the HMMWV (engine idle changed pitch), however the inverter operated fine.

3.2.2.3 Peak Efficiency. Using the configuration in Figure 4, we were able to gather measurements that allowed us to compute efficiency. We varied the load and took current and voltage measurements at 250W increments. The highest efficiency we calculated was 89.66%, although all of the numbers were above 85%. It was agreed that these numbers were satisfactory to MARCORSYSCOM. These numbers can be found in Appendix A.

3.2.2.4 No Load Current Draw. This characteristic was retested using the HMMWV power, but the value varied due the varying input voltage to the Inverter (HMMWV battery voltage varied because of engine alternator). The values we saw were between 0.9 A and 1.01 A, using the HMMWV power supply.

3.2.2.5 Output Waveform. This characteristic was tested on the bench, but because the power supply could not supply high power, we tested this again using the HMMWV power. We swept the load in 250 W increments, and measured the total harmonic distortion (THD). The values we got were between 0.65% and 0.87%, depending on load. These measurements can be found in Appendix A. See Figure 5 for a graph of the Frequency response that we gathered using the Agilent Oscilloscope. This chart shows that there is only minor distortion in the output signal of 156.9 V Peak (110.9 Vrms).

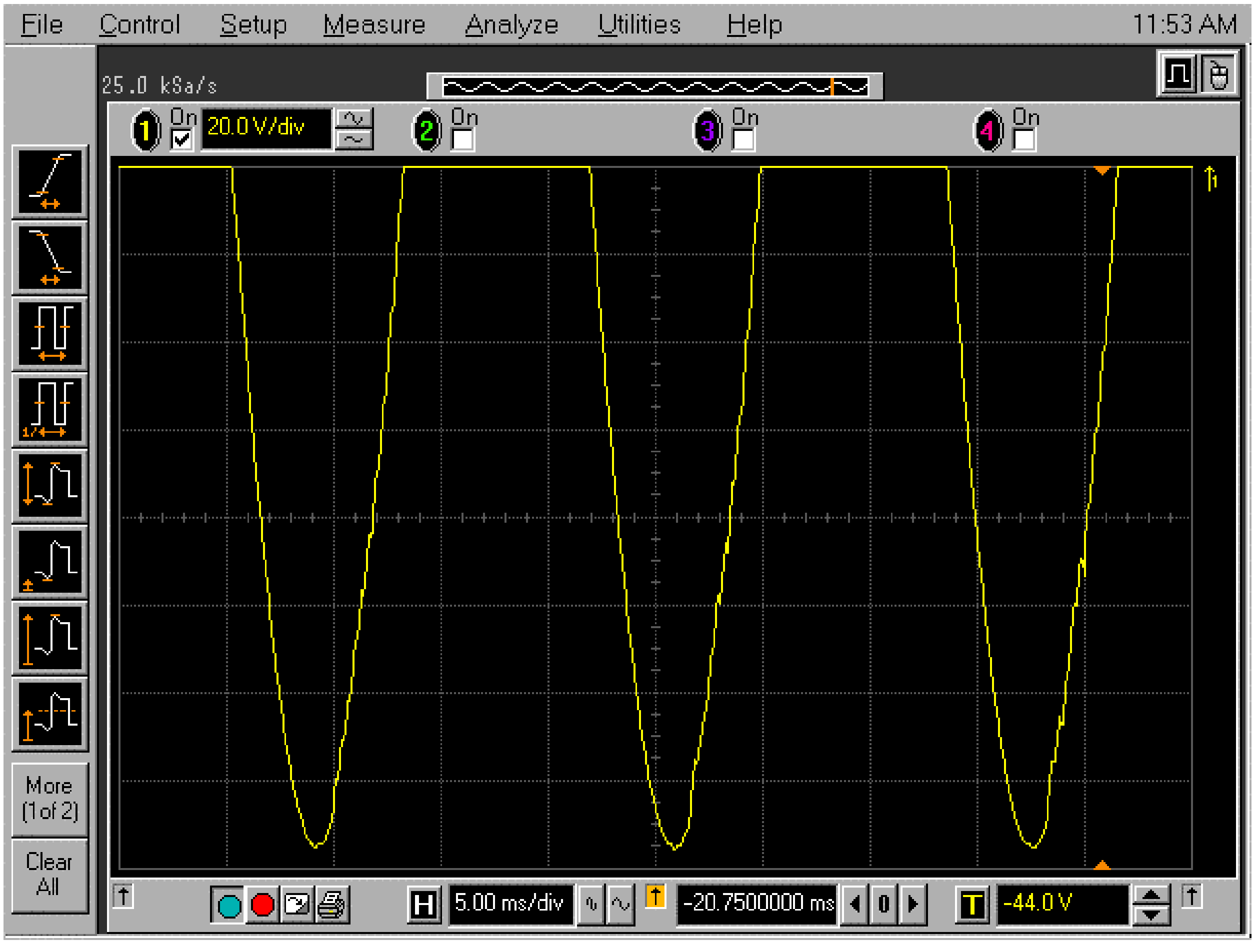

Figure 5: Frequency response of 110 VAC output of Inverter, when connected to HMMWV.

3.2.2.6 Output Frequency. The output frequency was monitored using the HMMWV power supply, and again it never varied from 60.00 Hz.

3.3 GFCI Test Results. The QP-1800 is equipped with Ground Fault Circuit Interrupters (GFCI) protected outlets. (See Appendix B for a review of GFCI.) GFCI provides ground fault protection for the equipment and people who come into contact with the Inverter. Under normal circumstances, a power strip can be plugged into a GFCI protected outlet with no problems. However, Iris Technology states in the Owner's Manual that there may be a problem operating their GFCI outlets with certain surge suppressors, and with certain 3 wire grounded (and even 2 wire non-grounded) equipment. Some equipment leak a little bit of current back to the outlet, which may be interpreted as a ground fault current leak. The result of that incompatibility was nuisance tripping of the GFCI. The purpose of this GFCI test was to investigate these potential trouble areas, and identify possible surge suppressors that would not work with the QP-1800. To do this test, we operated the inverter off the HMMWV power. We plugged various power strips, surge suppressors, and Uninterruptible Power Supplies (UPS) into the QP-1800 Inverter. Then we plugged a variety of electrical devices into the power strips, etc. The main electrical components we used were a heat gun (which drew about 70 Amps, according to the display on the Inverter), and a power drill (which drew about 15 Amps constant and surged higher when starting the motor). A detailed list of the equipment used can be found in Appendix C. (The display on the Inverter showed over 80 Amps being pushed by the Inverter, but the test team does not believe the Voltage/Current measurements on the Inverter to be very accurate.) We found no problems with any of the equipment operated, nor with any of the power strips, surge suppressors, and UPS used. It is unlikely that the USMC will use any equipment that will stress the system more than what occurred. Therefore, since no anomalies were found, the QP-1800 with local GFCI should be considered safe to use with most off the shelf power strips, surge suppressors, and UPS. (Since the QP-1800 provides surge suppression at the output, no additional surge suppressors should be needed.)

It should be noted that, during the environmental vibration test, the GCFI reset button did pop out during the Y axis testing (side to side vibration testing of random frequencies from 5 to 500 Hz.) However, the QP-1800 had no damage to it. The reset button was pushed in after the test, and it operated normally. It is the understanding of the test team that the QP-1800 will be non-operational when being transported; therefore, this nuisance reset is not an issue.

3.4 Safety Discussion. As with any electrical device, there are inherent safety hazards with operating this device. There are many military standards available for those not familiar. The QP-1800 can provide large amounts of power to electrical components. If the unit is not used properly, shock or electrocution may occur, or damage to equipment. However, with a solid safety plan, the unit will be safe to operate in and around the HMMWV. The following paragraphs will address the different concerns, and state how the unit should be operated to maintain a safe environment.

In the short circuit test conducted (Section 3.2.1.6), we verified that the QP-1800 would shut off in a short circuit condition. The Inverter did shut off power after closing the circuit (using the Square D load transfer switch), and we had to reset the circuit breaker on the inverter to restore power. Even though the unit is GFCI protected, a 15A circuit breaker is still needed to protect an overload condition from occurring. The circuit breaker protects the inverter and the equipment that it is powering. Furthermore, a circuit breaker is required for this type of device, and the Inverter meets the specification in MIL-HDBK-854A, Guideline 37, Section 4. This safety mechanism must not be disabled in any circumstance.

As stated, GFCI provides a valuable safety mechanism that is important to protecting people who come into contact with the Inverter or the equipment being powered. This safety mechanism is important because it cuts off power to the receptacle when it senses that current is leaking from Hot to Ground. This could occur is someone was touching the Hot (live) wire and standing in a puddle of water, or touching a plumbing fixture. Ground fault protection is an important safety feature for anyone working in wet or damp environments or outdoors, and should be considered a must have for the USMC. GFCI is an important safety tool, and should not be disabled in any condition. That said, and understanding that the USMC will employ GFCI, there are different options for employment, that will provide GFCI protection to the user and equipment.

One option for safe Inverter operation is to keep the GFCI enabled on the receptacle on the QP-1800 Inverter. Any mixture of power strips, UPS, and surge suppressors could be used (although surge suppression is already provided at the outlet). See Figure 6. This configuration would provide GFCI protection to all devices plugged into the Inverter. The advantage to this configuration is that the full protection is there by default, and cannot be disabled. The disadvantage is that if the GFCI trips on the Inverter (for any reason), power will be discontinued to every electrical device connected, until the GFCI is reset. Since the QP-1800 provides surge suppression (and GFCI) at the outlets, this configuration will be adequate for most needs, and any normal power strips may be used. This is the recommended configuration, especially if the equipment is low power, or if the equipment can withstand a momentary power loss (lights, battery chargers, laptops, printers, coffee makers, etc).

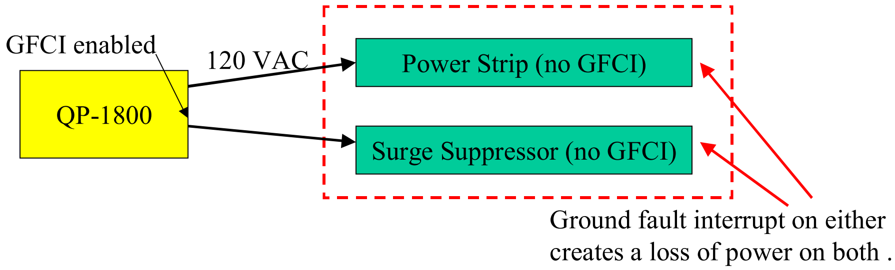

Figure 6: Safe operation configuration of QP-1800, with GFCI at the Inverter.

Another option for implementing the GFCI would be to remove the GFCI protection from the Inverter receptacle, and use surge suppressors that are GFCI protected. See Figure 7. This would allow the USMC to retain the GFCI protection for the people and equipment that come into contact. The advantage to this configuration is that if one of the electrical devices is shut off due to a ground fault current, only the units on that surge suppressor would be shut off, and the other items plugged into the Inverter would still be able to operate. This independence may be desirable for servers, or other devices that require a lot of power, and items that would not be able to withstand a momentary loss of power. The disadvantage to this configuration is that the onus is on the operator to ensure that he maintains this GFCI protection. (If a Marine bought a random power strip out in town, and hooked it up to his QP-1800 inverter, he might not have GFCI protection.) This GFCI remoting option might be more desirable if running extension cabling long distances through wet environments, where nuisance tripping may be an issue. In this case, it would be desirable to configure the QP-1800 as non-GFCI, and run 3 wire extension cabling to the remote location, to a GFCI protected duplex outlet.

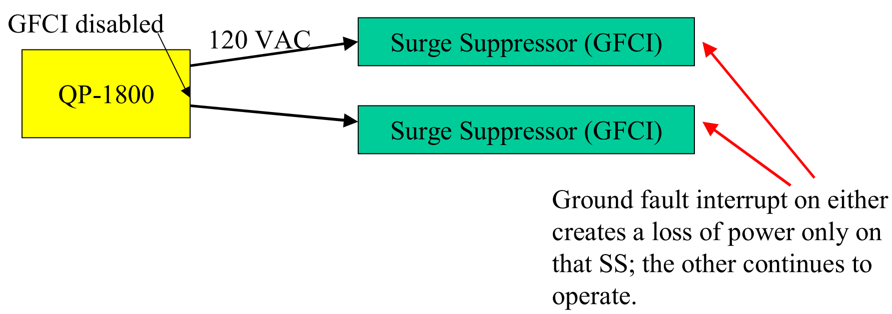

Figure 7: Safe operation configuration of QP-1800, with GFCI disabled on the Inverter, but enabled on surge suppressor outlets.

Safe operation of the QP-1800 involves more than the GFCI configuration. It also involves following basic battery and electricity cautions, such as wearing complete eye protection and clothing protection, cleaning the battery terminals before making connections, and not smoking in the immediate area. These are just some basic precautions. Per MIL-HDBK-454A, Guideline 1, Section 5.2, “proper instructions in accident prevention and first aid procedures should be given to all persons engaged in electrical work to fully inform them of the hazards involved.” Section 5.2.1 provides additional guidance with regard to shock hazards. A list of precautions can also be found in the QuietPower 1800 Inverter Owner’s Manual, Page 4.

3.5 Environmental Test Results. The environmental testing comprised of 2 major parts, temperature testing, and vibration testing. The vibration testing was in accordance with MIL-STD-810, but the temperature testing was abbreviated. The main focus of these tests was to make sure the Inverter would be able to withstand the operational hazards to which it could be subjected. All testing was performed in the Environmental lab of Building 3113.

3.5.1 Temperature Test Results. An abbreviated test was performed for temperature performance. The QP-1800 was placed in the environmental chamber, and taken slowly to low temperature. See Table 1 for specifications. After 24 hours at low temperature, it was brought back to room temperature, and then removed from the environmental chamber. The QP-1800 was then tested to make sure it still worked. Next, it followed a similar progression for high temperature tests. The results of the temperature tests were that the Inverter successfully operated after being subjected to temperature extremes. More details can be found in Appendix E.

3.5.2 Vibration Test Results. The vibration testing was performed in accordance with MIL-STD-810. The QP-1800 Inverter was bolted to the vibration table, using the rubber shock mounts included. It was subjected to 1 hour of random vibrations in the X axis, using random vibrations from 5 to 500 Hz. After the test, the Inverter was plugged in, and tested to verify the operation. A similar progression was followed for Y and Z axes. The QP-1800 operated successfully after each vibration test. The only anomaly noticed was that during the Y-axis test, the GFCI reset button popped out. This necessitated us pushing the button back in to reset it before we could do the functional performance test. The Y axis was vibrated again, without using the rubber mounts. The GFCI reset button did not pop out that time.

Using test tools available to the environmental lab personnel, it can be determined that the rubber shock mounts are useful in attenuating vibrations at high frequencies. However, at low frequencies (10 to 15 Hz), the shock mounts actually intensify the vibrations. It is the tester's assumptions that the USMC will not be using the Inverter when the HMMWV is on the move; therefore it will be acceptable to merely reset the GFCI reset button, in the case that the button does pop out. The shock mounts likely add protection against shock, so they should not be removed, unless operation on the go becomes an issue.

3.6 Impact of Test Environment. The test environment under which the Inverter was tested has the potential for being quite different than an operational environment. However, every attempt was made to make the testing as realistic as possible. One major difference is that the USMC will often be operating in wet and damp environments. This testing that occurred, even with the HMMWV, was in an air-conditioned laboratory. The wet and damp environments have a greater chance of tripping of the GFCI circuit.

3.6.1 Item Tested. The item tested was the QP-1800 Power Inverter, sold by Iris Technology. This is an off the shelf product, and the item tested should be considered representative of any sample of QP-1800 Inverters.

One item of note is that the testers used the 2/0 AWG cables that were included in the package from Iris Technology. Even though the power cables weren't a formal tested item, it is important to explore options for fielding. The cable provided proved to be very effective and practical for our purposes. We measured a 0.25 V loss across the 12 foot long 2/0 AWG cable (from battery terminals to Inverter), at approximately 80 Amps. There are inherent voltage losses in any cable, but as the cable gets smaller, the losses per foot increase. (We also measured about 0.3 V loss across the 3 foot #4 AWG cable, when using the power supply, at about 40 A.) Therefore, a 1/0 or 2/0 cable is recommended for use.

Another issue is flexibility. The larger cables have greater flexibility. The 2/0 cable provided ample flexibility to move around. A smaller cable, such as the #4 AWG cable we used with the power supply, will be very rigid, and will not react well to moving around. It is possible that a rigid cable could become damaged or broken if subjected to a lot of bending. If the Inverter is going to be mounted in the HMMWV and never moved, then cable flexibility is not a serious issue. However, if the Marines will need to move the Inverter in and around the HMMWV, it is recommended that they use a 1/0 or 2/0 cable.

3.6.2 Test Conditions. The test environment in Building 3112 was an air-conditioned laboratory. Although we did open the door to let in the HMMWV we used for testing, the air was still relatively controlled. Also, for cables, we used the 2/0 AWG cable with NATO slave receptacle that Iris Technology included in the package. This cable was approximately 12 feet long. This cable is adequate for operating the Inverter anywhere near the HMMWV. However, if another gauge or length of cable is used, it could make a small difference in the operation of the Inverter.

3.6.3 Test Description. Tests were conducted in accordance with the SPAWAR HMMWV Power Inverter Candidate Test Plan, dated 21 May 2001. All items were configured and tested using normal laboratory methods. All tests were performed at laboratory ambient temperature, relative humidity, and atmospheric pressure conditions. The test plan was developed to test critical performance and functionality elements of the Inverter. An additional evaluation process was added to include the GFCI characteristics, and to address safety of the Inverter.

3.6.4 Test Equipment and Instrumentation. Electrical test equipment is very sensitive to many factors, and often loses calibration over time. All test equipment used for this test had a valid calibration, or was labeled NCR (no calibration required). See Appendix D for a complete list of equipment used. The test equipment used was generally in compliance with MIL-PRF-28800F, General Specification for Test Equipment for use with Electrical and Electronic Equipment.

3.6.5 Test Observations and Evaluations. Test documentation is included as appendices provided in the individual specimen reports. This includes electrical test data and environmental test data. Environmental reports contain vibration x-y plots of amplitude verses frequency obtained from the accelerometer responses acquired during the test events. Photographs of most test set-ups and effects are also included.

3.6.6 Other Tests. This test reporter talked on the phone to other active duty Marines who have used the QP-1800, both in a test environment, and operationally in the field. They report that the unit has held up well in the tests. They also say that the unit has performed well over a long period of time (2 years).

3.7 Summary. In the opinion of the test team at SPAWAR Systems Center Charleston, the QP-1800 is a quality Inverter that will fit the needs of the USMC. In the bench test, we found that the unit met or came close to meeting all required specifications. The important thing is that the unit did not have any failures. During the GFCI testing, we found that the unit worked with a variety of different electrical components, and should work with most off the shelf products. If the USMC is planning on fielding the Inverter with only certain power strips or surge protectors, it is recommended that they test it first in the lab. Safety is the most important issue, and 2 different configurations were given with respect to the GFCI. Finally, the environmental test proved that the Inverter would be able to support almost any environment that the Marines will be in.

Appendix A – Test Data

Load (Watts)	Distortion (%)
0W	0.675
250	0.69
500	0.65
750	0.66
1000	0.72
1250	0.75
1500	0.87

Table A-1: Total Harmonic Distortion Characteristics (using HMMWV)

Load (Watts)	LV warning (DC Volts)	LV warning (DC Amps)	LV shutdown (DC Volts)
0	21.19	1.01	19.98
250	21.2	19.1	19.88
500	21.22	32.74	20.11
750	21.1	46.74	19.87

Table A-2: Low Voltage Warning and Shutdown Measurements (Bench Test)

Load (Watts)	HV warning (DC Volts)	HV warning (DC Amps)	HV shutdown (DC Volts)
0	31.66	1.01	32.06
250	31.7	12.78	32.08
500	31.76	21.82	32.05
750	31.69	31.8	32.06

Table A-3: High Voltage Warning and Shutdown Measurements (Bench Test)

Load	Input Current (DC)	Output Current	Output Voltage	Input Voltage
0	1.01	0	121.5	28.3
250	14.2	3	120.1	28.3
500	24.3	5	119.4	28
750	35	7.1	118.8	27.7
1000	45.3	9.2	118.1	27.5
1250	56	11.25	117.5	27.2
1500	67.45	13.25	116.8	26.8

Table A-4: Steady State Characteristics (Engine Running)

Load	Power out (W)	Power in (W)	efficiency
0	0	0	N/A
250	360.3	401.86	89.66%
500	597	680.4	87.74%
750	843.5	969.5	87.00%
1000	1086.5	1245.75	87.22%
1250	1321.88	1523.2	86.78%
1500	1547.6	1807.66	85.61%

Table A-5: Efficiency Calculations

Appendix B – GFCI Information

The QP-1800 is equipped with Ground Fault Circuit Interrupters (GFCI). (GFCI are small circuit breaker-like devices that shut off the associated circuit if there is an electrical "leak" which may cause a "ground fault" - a shock hazard due to moisture or a damp floor. A GFCI works by comparing the amount of electrical current coming into a circuit (on the black wire) with the amount leaving (on the neutral or red wire). If more current enters the circuit through phase wire than leaves through neutral wire, there is a current leak or ground fault. GFCI is able to detect as little as a 0.005 amp leak, a GFCI can shut down a circuit within 0.025 seconds, helping prevent serious electrical shocks. A fault current as low as 4 mA to 6 mA activates the GFCI and interrupts the circuit. Once activated, the fault condition is cleared and the GFCI manually resets before power may be restored to the circuit.)

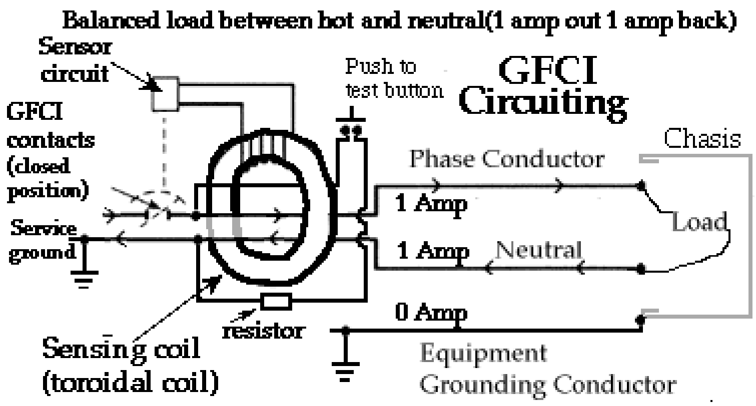

Figure B-1: Balanced GFCI Circuit (from http://www.codecheck.com/gfci_principal.htm)

Appendix C – GFCI Test Equipment List

Clary Onguard PC Model UPSI- 800VA – 1G/01
Master Heat Gun Model HG-751B   Master Appliance Corp
Belkin Surge Master Transient Voltage Surge Suppressor F5C572
Gemini Surge Model VG-307
TrippLite Transient Voltage Surge Suppressor Model IBR-12 (Basic and Enhanced Noise Suppression)
Power Sentry Power Tap Model:133

Appendix D – Electrical Test Equipment List

1. Variable DC Power Supply (Sorensen DCR40-60A)
2. Load Bank (Avtron K490)
3. Distortion Analyzer (Hewlett-Packard (HP) 334A
4. Digital Multimeter (Fluke 32 Clamp Meter)
5. Digital Wattmeter (Clarke Hess Model 235)
6. Spectrum Analyzer (HP Dynamic Signal Analyzer Model 3561A)
7. Oscilloscope (Agilent Infinium 5438A).
8. Current Probe (Tektronix A6302/A6303)
9. Current Probe Amplifier (Tektronix TM5020A/AM503A)
10. Load Transfer Switch (Square D Double Throw 200A Load Transfer Switch, #92454)

Appendix E – Environmental Test Report

IRIS TECHNOLIGIES CORPERATION
POWER INVERTER MODEL QP-1800
TESTED FOR
SPAWAR Systems Center Charleston Code 613

11 June, 2001

1. **Item Tested.** IRIS Power Inverter Model QP-1800 is being tested to determine if it will operate in the military environment.

2. **Test Description.** A modified Low Temperature test was conducted at –40 C for 24 hours. A modified High Temperature test with uncontrolled humidity was conducted at 70 C for 24 hours. A Random Vibration test using the parameters from MIL-STD-810F Method 514 for secured equipment transportation composite wheeled vehicle at one hour per axis. The vibration test was conducted with the Unit Under Test (UUT) mounted on vibration isolators. After the initial testing was completed, it was requested to run the Y-axis test again with the UUT not mounted on vibration isolators. These tests were selected to excite the equipment at the extremes of the operating environment. Operational checks were conducted after each segment of the tests by removing the UUT from the test chamber or vibration table, connecting it to a 24-Volt DC power source, and using the inverter produced power to operate an oscilloscope.

3. **Test Equipment and Instrumentation.** A 24-volt DC power supply was utilized to power the inverter, and an oscilloscope was used to check the AC power provided by the inverter.

4. **Observations.** The UUT provided proper power after each test, with only one minor discrepancy. After the Y-axis test the power interrupt circuit breaker was found to be in the interrupt position, after it was reset the UUT had normal operation. After the retest on the Y-axis with the UUT not mounted on vibration isolators, the circuit breaker did not trip, and the UUT functioned normally.

5. **Conclusions.** The Power Inverter Model QP-1800 is recommended for use in wheeled military vehicles.